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AN ASSESSMENT OF THE USE OF SLIMICIDE CHEMICALS AT WOOD PULPING FACILITIES IN THE ATLANTIC REGION

Surveillance Report EPS-5-AR-02-03
Atlantic Region

Canada

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AN ASSESSMENT OF THE USE OF SLIMICIDE CHEMICALS AT WOOD PULPING FACILITIES IN THE ATLANTIC REGION

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Environmental Protection Branch
Environment Canada
Atlantic Region

November, 2002

EPS-5-AR-02-03

ABSTRACT

In early 1986, the pulp and paper mills in the Atlantic Provinces were surveyed by Environment Canada to determine the slimicide use pattern for that industrial sector. Slimicides, are agents which are generally used throughout the pulping process to control algae and other microorganism and macroorganism growth (Arnold, 1994). As a follow up to the 1986 study by Environment Canada, surveys were undertaken in 1997 and 2000 to determine how the slimicide use pattern at such facilities had changed over the last 14 years. The questionnaires requested information on types, quantities and application rates of slimicides used in any facility systems, and also other methods used to control algae and other micro/macroorganism growth.

Nineteen facilities were located in the Atlantic Region, all of which participated in the surveys. Ten facilities were located in New Brunswick, six in Nova Scotia, and three in Newfoundland. There have been and currently are no pulp and paper facilities in Prince Edward Island. In 2000, 11 of the 19 facilities were utilizing slimicides registered under the Pest Control Products Act (PCPA) by the Pest Management Regulatory Agency (PMRA), to control micro/macroorganism growth in the pulp slurry, in other facility systems (i.e., cooling towers) to control biofouling during operations, or as a preventative measure during shutdown procedures at selected plants.

A review of the 1997 and 2000 data indicated that although the number of mills using slimicides has decreased (from 12 companies in 1997 to 11 in 2000), the total volume of slimicides used has increased (from 75,690 kg to 121,561 kg of active ingredients). Facilities in New Brunswick accounted for approximately 71.29% of the total increase in slimicide use from 1997 to 2000. In addition, the types of slimicides used have changed markedly, none of the registered slimicides used in 1986 were used in 2000. Based on responses from the questionnaires, the change in the volume and type of slimicides used may be the result of increased facility production, changing milling processes, an increased tolerance by microbes to the older slimicides, or a lower toxicity and/or cost of the newer slimicides.

In 2000, five active ingredients (a.i.) of slimicides were identified in use in Atlantic Canada in volumes greater than 10,000 kg/year; sodium hypochlorite (35,625 kg), potassium dimethyldithiocarbamate (30,000 kg), sodium bromide (15,000 kg), 2-(thiocyanomethylthio)benzothiazole (TCMTB) (10,600 kg), and methylene bis(thiocyanate) (MBT) (10,600 kg). The toxicity of each of these substances to aquatic organisms was evaluated using published information, with TCMTB and MBT having the highest toxicity to *Daphnia magna* and/or Rainbow trout (*Oncorhynchus mykiss*).

There is currently no requirement for monitoring effluents specifically for the presence of slimicides, and as a result, there is very little information regarding typical concentrations in waste streams. There are, however, requirements for testing mill effluent for acute and chronic toxicity to aquatic organisms and some of those tests indicate toxic effluents. Due to the lack of information regarding the presence of slimicides and their degradation compounds in effluent and receiving environments, this report recommends that slimicides and their degradation products should be monitored in effluent from companies using slimicides in their facilities, particularly those facilities that fail the required acute and/or chronic aquatic toxicity tests.

RÉSUMÉ

Au début de l'année 1986, Environnement Canada a entrepris une étude des fabriques de pâtes et papiers dans les provinces de l'Atlantique en vue de déterminer les méthodes d'utilisation de myxobactéricides dans ce secteur industriel. Les myxobactéricides sont des agents qui interviennent généralement tout au long du procédé de réduction du bois en pâte afin de limiter la prolifération des algues et la croissance des microorganismes et des macroorganismes (Arnold, 1994). Dans la foulée de l'étude de 1986 menée par Environnement Canada, d'autre travaux de suivi ont été entrepris en 1997 et en 2000 afin d'établir les changements de méthodes d'utilisation des myxobactéricides à ces usines en 14 ans. Au moyen de questionnaires, des renseignements ont été recueillis sur les types, les quantités et le taux d'application de myxobactéricides dans des installations, et également sur les méthodes utilisées pour limiter la prolifération des algues et la croissance de microorganismes et de macroorganismes.

Les dix-neuf fabriques de la région de l'Atlantique, dont dix sont situées au Nouveau-Brunswick, six en Nouvelle-Écosse et trois à Terre-Neuve, ont participé aux études. Il n'y a jamais eu de fabrique de pâtes et papiers à l'Île-du-Prince-Édouard, et il n'y en a toujours pas. Par ailleurs, ces études révèlent que, en 2000, onze des dix-neuf installations utilisaient des pesticides homologués par l'Agence de réglementation de la lutte antiparasitaire (ARLA), en vertu de la *Loi sur les produits antiparasitaires* (LPA), afin de limiter la croissance des micro/macroorganismes dans les boues des usines de pâtes et papiers, et dans d'autres systèmes (p. ex. tour de refroidissement) pour éviter l'encrassement biologique pendant les opérations, ou à titre de mesure de prévention pendant l'arrêt des opérations à certaines installations.

Un examen des données de 1997 et de 2000 indique que, malgré la diminution du nombre de fabriques utilisant des myxobactéricides (nombre qui est passé de 12 usines en 1997 à 11 en 2000), le volume total de myxobactéricides a augmenté (de 75 690 kg à 121 561 kg d'ingrédients actifs). Les usines du Nouveau-Brunswick sont responsables d'environ 71,29 % de l'augmentation totale des myxobactéricides entre 1997 et 2000. De plus, les types de myxobactéricides utilisés ont changé de façon notable. Des myxobactéricides homologués et utilisés en 1986, on n'en retrouve aucun en 2000. Les réponses au questionnaire montrent que les changements observés en ce qui a trait au volume et aux types de myxobactéricides utilisés peuvent être attribuables à un accroissement de la production des usines, à une modification de leurs procédés, à une plus grande tolérance des microbes aux anciens myxobactéricides ou à une plus faible toxicité et/ou au coût des nouveaux myxobactéricides.

En 2000, on a identifié cinq ingrédients actifs (i.a.) qui entrent dans la composition des myxobactéricides utilisés dans le Canada atlantique dans des volumes supérieurs à 10 000 kg/an : hypochlorite de sodium (35 625 kg), diméthyldithiocarbamate de potassium (30 000 kg), bromure de sodium (15 000 kg), 2-(thiocyanométhylthio) benzothiazole (TCMTB) (10 600 kg), méthylène bis (thiocyanate) (MBT) (10 600 kg). Le niveau de toxicité de chacune de ces substances pour les organismes aquatiques a été évalué d'après l'information publiée, et on a constaté que le TCMTB et le MBT présentaient une toxicité supérieure pour le *Daphnia magna* et/ou la truite arc-en-ciel (*Oncorhynchus mykiss*).

La surveillance des effluents, notamment en vue de détecter la présence de myxobactéricides, n'étant pas obligatoire actuellement, on dispose de très peu d'informations sur les concentrations types dans les flux de déchets. Toutefois, les usines doivent analyser leurs effluents afin de déterminer le niveau de toxicité aiguë et chronique pour les organismes aquatiques et quelques-unes de ces tests indiquent les effluents toxiques. En raison de la rareté des données sur la présence de myxobactéricides et de leur composés de dégradation dans les effluents et les milieux récepteurs, le présent rapport recommande la surveillance des effluents des usines où des myxobactéricides et leurs agents de dégradation sont utilisés, en particulier celles qui échouent les tests de toxicité aiguë et/ou chronique pour les espèces aquatiques.

ACKNOWLEDGMENTS

The authors would like to acknowledge all of the pulp and paper industries that participated in the study in Atlantic Canada. Their timely responses to the questionnaires and sharing of information was the basis of this report. In addition, thanks also goes to the following individuals who provided comments on the draft version of this report: Les Rutherford, Kay Kim, MT Grant, Bill Ernst, and Gary Julien of Environmental Protection Branch.

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1. INTRODUCTION

Aqueous processes in pulp mills have temperatures and pH conditions which are ideal for promoting micro and macroorganism growth. Therefore, *slimicides* are often applied throughout the pulping process to control microorganisms (i.e. algae, bacteria, and fungi) and macroorganisms (i.e. invertebrates and macroalgae), and as a preventative measure during shutdown procedures of selected plants. Microorganisms can colonize on pipework, which can impair heat exchange efficiency, and macroorganisms can form a thicker layer which may reduce or stop the flow of water through the pipework (Arnold, 1994).

There has been limited scientific investigation of industrial chemicals classified as slimicides (Eriksson, et. al., 1995). A previous study reported that the biocides used in the pulp and paper industry in Atlantic Canada identified fourteen different active ingredients in registered slimicides used in Atlantic Canada, including sodium bromide, liquid sodium hypochlorite, chlorine gas and 1,2-dibromo-2,4-dicyanobutane (Arnold, 1994). Based on the information provided by facilities in Atlantic Canada to Environment Canada in the survey, pulp and paper industries tend to be fairly consistent in terms of their seasonal slimicide usage, with lower quantities typically required in the winter months due to growth rates which are temperature limited.

In 1986, Environment Canada canvassed twenty pulp and/or paper mills in the Atlantic Region to determine slimicide use patterns for that industrial sector. Facilities were surveyed in Nova Scotia, New Brunswick, and Newfoundland, however, no pulp and paper mills were or are in existence in Prince Edward Island. Fourteen of the twenty facilities (i.e. 70%) surveyed were using slimicides at that time. Approximately 17,000 kg active ingredient (a.i.) per year was reported to be in use during 1984-1986. In 1997, a follow-up survey was undertaken as a joint project between the Pest Management Regulatory Agency (PMRA) and Environment Canada. The objectives of that survey were to determine if slimicide use at pulp and paper facilities in Atlantic Canada had changed over the last decade. A further follow-up survey was conducted in 2000 to update the 1997 results.

The objectives of this report are to compile and summarize the data from the three surveys in order to identify temporal changes in the quantities, identities and use patterns of slimicides in the pulp and paper sector. In addition, this report also discusses the ecotoxicity of slimicides to aquatic receptors and provides recommendations regarding slimicide effluent testing in Atlantic Canada.

2. METHODS

Questionnaires were used as the method of data collection for the 1997 and 2000 studies. The questionnaire was developed in 1997 and requested information on the types of slimicides currently or historically in use at pulp and paper facilities in the Atlantic Region (see Appendix A for a copy of the 2000 questionnaire). The survey involved a two-part questionnaire such that the facility could identify the slimicides used specifically in the pulping process and also list those products which may be used to control biofouling in other facility systems (i.e. cooling water). Specific data was requested on types of chemicals used, volumes used, application rates, application times and locations, monitoring of slimicides in effluents, and any other information pertinent to the use of slimicides in their operations. The 1997 questionnaire was mailed out to 23 facilities in the Atlantic Region (Table 1). Follow-up telephone calls were made to those facilities that did not respond to the questionnaire. Four of the 23 companies initially contacted indicated that they did not produce pulp and were therefore eliminated from the overall survey, since the study was targeting facilities with pulping operations. Therefore, for the 2000 survey, only 19 facilities were contacted.

Between 2000 and the writing of this report, several companies had undergone mergers or buyouts and the names of the facilities have changed. The revised list of facilities is presented in Table 1. Where company names have changed, the former names of the companies (as of 2000) have been used for the remainder of the report to be consistent with the results of the 2000 survey.

Table 1: Facilities Contacted in 1986, 1997 and 2000, and Use of Slimicides in 2000

	Company	Location	Using Slimicides in 2000?	Surveyed in 1997 and 2000	Surveyed in 1986?
	Nova Scotia				
1	ABT Canada Ltd. Canexel Hardboard [1]	Chester	No	Yes	Yes
2	Barnhill Contracting Ltd.	Belmont	Not contacted	No (no pulp)	No
3	Bowater Mersey Paper Co. Limited	Liverpool	Yes	Yes	Yes
4	CKF Inc. [2]	Hantsport	No	Yes	Yes
5	Kimberly-Clark Nova Scotia [3]	New Glasgow	No	Yes	Yes[1]
6	L'Imprimerie Lescar bot Limitee	Yarmouth	Not contacted	No (no pulp)	No
7	Minas Basin Pulp and Paper	Hantsport	Yes	Yes	Yes
8	Paper Knights Publishing	Sheet Harbour	Not contacted	No (no pulp)	No
9	Stora Enso Port Hawkesbury [4]	Port Hawkesbury	Yes	Yes	Yes
	Newfoundland				
10	Abitibi Price Inc.- Grand Falls [5]	Grand Falls-Windsor	Yes	Yes	Yes
11	Abitibi Price Inc. - Stephenville [5]	Stephenville	No	Yes	Yes
12	Corner Brook Pulp & Paper Limited	Cornerbrook	Yes	Yes	Yes
	New Brunswick				
13	AV Cell Inc. [6]	Atholville	No	Yes	Yes[2]
14	Bowater Maritimes Inc. [7]	Dalhousie	Yes	Yes	Yes[3]
15	Fraser Papers Inc.	Edmunston	Yes	Yes	Yes
16	Irving Paper Inc. [8]	Saint John	Yes	Yes	Yes[4]
17	Irving Pulp & Paper Limited	Saint John	No	Yes	Yes
18	Irving Tissue Limited [9]	Saint John	No	Yes	Yes[5]
19	Lake Utopia Paper	St. George	Yes	Yes	Yes
20	UPM-Kymmene [10]	Miramichi	Yes	Yes	Yes[6]
21	St. Anne Nackawic Pulp Company Limited	Nackawic	No	Yes	Yes
22	Smurfitt-Stone Container (Canada) Inc. [11]	Bathurst	Yes	Yes	Yes[7]
23	Tann Paper Limited	Woodstock	Not contacted	No (no pulp)	No

[1] Formerly Canexel (1986) and currently Louisiana Pacific Canada Limited (2002)
[2] Formerly Can Keyes Fibre (1986)
[3] Formerly Scott Maritime (Kraft Mill) (1986)
[4] Formerly Stora (1986)
[5] Formerly Abitibi-Price Inc. (1986)
[6] Formerly Alcell Forest Products (1997); Fraser's - Atholville (1986)
[7] Formerly Avenor Maritimes Inc.(1997); NBIP (1986)
[8] Formerly Rothesay Paper (1986)
[9] Formerly Kimberly Clark - Saint John (1986), and currently Irving Pulp and Paper Limited and Irving Tissue Company have amalgamated into Irving Pulp, Paper and Tissue (2002) - both discharge effluent through the main mill outfall
[10] Formerly REPAP New Brunswick (1997); Miramichi Pulp & Paper (1986) - two mills - kraft mill in Miramichi and groundwood mill in Nelson, NB (groundwood mill was not part of the original 1986 survey or subsequent surveys in 1997 and 2000)
[11] Formerly Stone Container Canada (1997); Bathurst Consolidated (1986)

3. RESULTS AND DISCUSSION

3.1 Registered Slimicides

Registered slimicides, as they are referred to in this report, are those slimicides which have been registered under the Pest Control Products Act (PCPA) by the Pest Management Regulatory Agency (PMRA) as acceptable pesticides for use in Canada.

3.1.1 Slimicide Use by Facilities in the Atlantic Region

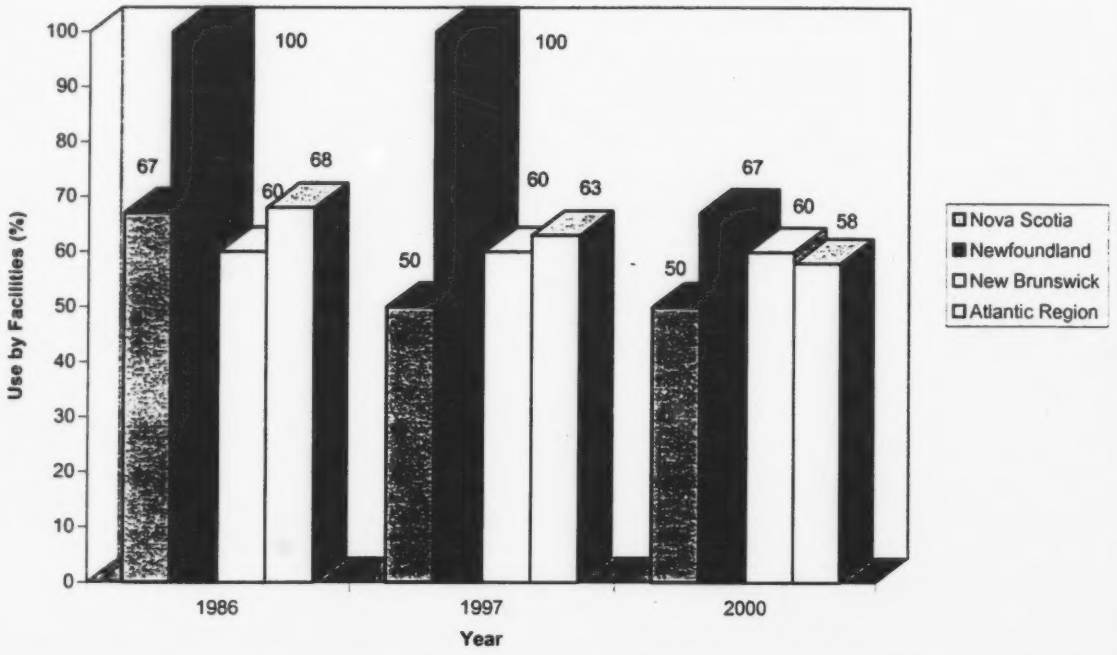
Of the 19 companies identified as producing pulp in Atlantic Canada (as presented in Table 1), New Brunswick had the highest number with 10 facilities while Nova Scotia had 6 facilities and Newfoundland had 3 facilities. All companies provided information for both the 1997 and 2000 surveys on slimicide use.

Of those facilities in Atlantic Canada, 11 (58%) reported that they were using slimicides to control micro and/or macroorganism growth during the pulping process and/or in other facility systems in 2000 (Figure 1). Those results are lower than survey results in 1986 and 1997, when slimicides were reported to be used by 13 (68%) and 12 (63%) pulp and paper facilities, respectively. Thus, in total, the percentage of facilities across Atlantic Canada in this study using slimicides has decreased from 68% in 1986 to 58% in 2000. No explanation was provided by the two facilities using slimicides in 1986 but not in 1997 or 2000. The cleaning of filters and good housekeeping rules was indicated to be the reason the one facility using slimicides in 1997 was not using them in 2000. In addition, the two facilities not using slimicides in 1986, but using them in 1997 and 2000, provided no explanation as to why they began using them subsequent to 1986.

The number of facilities using slimicides in Nova Scotia has decreased from 67% in 1986 to 50% in 2000. Similarly, the percentage of pulp and/or paper facilities using slimicides in Newfoundland has also decreased from 100% in 1986 to 67% in 2000. In the province of New Brunswick, the percentage of pulp and/or paper facilities using slimicides has remained unchanged at 60% between 1986 and 2000.

Figure 1 presents the percentage of facilities in Atlantic Canada that were using slimicides in 1986, 1997 and 2000.

Figure 1: Percent of Facilities Using Registered Slimicides in the Atlantic Region



3.1.2 Types and Volumes of Slimicides in Use in Atlantic Canada

Table 2 provides the identify and quantities of registered slimicide use by individual facilities in the years 1986, 1997 and 2000. The amount of active ingredients (a.i.) used for each slimicide was calculated by multiplying the annual usage of product by the percent active ingredient(s) (a.i.s) as reported in the Regulatory Information on Pesticide Products (RIPP) database (PMRA, 2000). In addition, for those slimicides that were in use in 2000, the facility process where they were used has also been identified.

Table 2: Types and Volumes of Slimicides Used in Atlantic Canada

Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
NOVA SCOTIA								
ABT Canada Ltd.	-	-	-	-	-	-	-	-
Bowater Mersey Paper Company Limited	Spectrum RX1000	24956	Bis(trichloromethyl)sulfone (5.3%) N-alkyl dimethyl benzyl ammonium chloride (16%)	-	-	330	Broke tank	Not used
	Busan 1009	19077	Methylene bis(thiocyanate) (10%) 2-(thiocyanomethylthio) benzothiazole (10%)	-	31	-	-	-
	Betz-Dearborn Spectrum RX3605	16113	Bis(trichloromethyl)sulfone (20%)	880	-	-	-	-
	Busan 25	12010	S-(2-hydroxypropyl)thiomethane sulfonate (11.7%) 2-(thiocyanomethylthio) benzothiazole (13.3%)	1,000	-	-	-	-
	Busan 52	12008	Potassium n-hydroxymethyl-n-methyldithiocarbamate (32%) Sodium salt of 2-mercaptobenzothiazole (8%)	2,600	-	-	-	-
CKF Inc.	Alchem 7644	15767	Nabam (10.8%) Sodium dimethyldithiocarbamate (17.6%)	850	-	-	-	-
	Alchem 57039	15514	Not identified	13.5	-	-	-	-
	Nalcon 7648	17951	N-alkyl dimethyl benzyl ammonium chloride (31.9%) Dialkyl methyl benzyl ammonium chloride (0.1%)	1,121	-	-	-	-
Kimberly-Clark Nova Scotia	-	-	-	-	-	-	-	-
Minas Basin Pulp and Paper	Busan 1202	22931	Gluteraldehyde (50%)	-	-	1,361	2x daily to storage tower	not used

Table 2: Types and Volumes of Slimicides Used in Atlantic Canada

Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
	Busan 1167	22577	Sodium bromide (40%)	-	-	5,400	not used	Constantly in white water loops of paper machine
	Busan 90	12002	2-bromo-4'-hydroxyacetophenone (30%)	-	300	-	-	-
	Busan 94	17571	2,2-dibromo-3-nitrilopropionamide (20%)	-	400	-	-	-
	Busan 85	18619	Potassium dimethyldithiocarbamate (50%)	-	750	-	-	-
	Alchem 7644	15767	Nabam (10.8%) Sodium dimethyldithiocarbamate (17.6%)	1,420	-	-	-	-
	Nalcon 7648	17951	N-alkyl dimethyl benzyl ammonium chloride (31.9%) Dialkyl methyl benzyl ammonium chloride (0.1%)	640	-	-	-	-
Stora Enso Port Hawkesbury	Spectrus OX1205C	17469	Sodium hypochlorite (10.8%)	-	-	1,296	Constantly to warm water tank, clay silo	not used
	Busan 1009	19077	2-(thiocyanomethylthio) benzothiazole (10%) Methylene bis(thiocyanate) (10%)	-	-	6,400	Constantly to warm water tank, clay silo	not used
	Busan 52	12008	Potassium n-hydroxymethyl-n-methyldithiocarbamate (32%) Sodium salt of 2-mercaptobenzothiazole (8%)	52	27	-	-	-
NOVA SCOTIA TOTAL				**8,576**	**1,508**	**14,787**	3 facilities	1 facility
NEWFOUNDLAND								
Abitibi-Consolidated Inc. - Grand Falls Division	Alchem 6C01	19863	1-alkyl(C8-C18)-1,3-propanediamine acetate (20%)	-	-	1,060	24 x per day for 15 min. to Paper Machine 7 warm water tank	not used
	Nalcon 7649	17575	2,2-dibromo-3-nitriolpropionamide (20%)	-	-	170	24 x per day for 15 min. to Paper Machine 3 warm water tank	not used
	Busan 52	12008	Potassium n-hydroxymethyl-n-methyldithiocarbamate (32%) Sodium salt of 2-	1227	800	-		

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Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
			mercaptobenzothiazole (8%)					
	Betz Slimetrol RX-34	13598	Nabam (15%) Sodium dimethyldithiocarbamate (15%)	992	140	-	-	-
Abitibi-Consolidated Inc. - Stephenville Division	Acti-brom 1338	21678	Sodium bromide (40%)	-	2,568	-	-	-
	Busan 52	12008	Potassium n-hydroxymethyl-n-methyldithiocarbamate (32%) Sodium salt of 2-mercaptobenzothiazole (8%)	2,160	-	-	-	-
Corner Brook Pulp & Paper Limited	Busan 1228D	22863	2-bromo-2-nitropropane-1,3-diol (10%)	-	-	2,800	Constantly to water used for pulping recycled pulp	Constantly to hot water supply for mill operations; added to water used for mixing/ making down polymers
	Chimtox 920	22101	2-bromo-2-nitropropane-1,3-diol (10%)	-	630	-	-	-
	Alchem 53010	15767	Nabam (10.8%) Sodium dimethyldithiocarbamate (17.6%)	440	-	-	-	-
NEWFOUNDLAND TOTAL				4,819	4,138	4,030	2 facilities	1 facility
NEW BRUNSWICK								
AV Cell Inc.	Alchem 321	16320	1-alkyl(C8-C18)-1,3-propanediamine acetate (20%)	120	-	-	-	-
Bowater Maritimes Inc.	Busan 85	18619	Potassium dimethyldithiocarbamate (50%)	-	-	3,000	Broke tank (Dec.-May)	
	Sodium hypochlorite	25536	Sodium hypochlorite (16.8%)			Quantity not specified	not used	Water coming into mill; a residual chlorine level is maintained
	Spectrum RX-9600	23963	2-bromo-2-nitropropane-1,3-dio (5.3%) N-alkyl dimethyl benzyl ammonium chloride (10%)	-	838	-	-	-
	Betz-Dearborn	16113	Bis(trichloromethyl)sulfone (20%)	2,640	1,927	-	-	-

Table 2: Types and Volumes of Slimicides Used in Atlantic Canada

Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
	Spectrum RX3605							
Fraser Papers Inc.	Nalco 7647	22946	2-methyl-4-isothiazolin-3-1 (0.37%) 5-chloro-2-methyl-4-isothiazolin-3-1 (1.13%)	-	-	150	None	applied 1 x paperboard coating batch (8 batches/day) and 3x in coating head
	Sodium hypochlorite	25536	Sodium hypochlorite (16.8%)			Quantity not specified	not used	May-Oct in cooling tower, used to generate steam
	Nalco 6C28	21182	Dissodium ethylenebis (dithiocarbamate) (15%) Sodium dimethyldithiocarbamate (15%)	-	1,200	-	-	-
	Nalco 7648	17951	N-alkyl dimethyl benzyl ammonium chloride (31.9%) Dialkyl methyl benzyl ammonium chloride (0.1%)	-	3,840	-	-	-
	Betz-Dearborn Spectrum RX3605	16113	Bis(trichloromethyl)sulfone (20%)	141	-	-	-	-
	Metasol CB210	18477	1,2-dibromo-2,3-dicyanobutane (10%)	40	-	-	-	-
Irving Paper	Nalco 6C40	19229	2-methyl-4-isothiazolin-3-1 (0.97%) 5-chloro-2-methyl-4-isothiazolin-3-1 (2.9%)	-	290	735	1 x/day on batch basis - treatment of delaminated clay, paper broke and retention aid	not used
	Acti-brom 1338	21678	Sodium bromide (40%)	-	2,140	-	-	-
	Betz Slimetrol RX-68	17390	2-methyl-4-isothiazolin-3-1 (0.37%) 5-chloro-2-methyl-4-isothiazolin-3-1 (1.13%)	57	-	-	-	-
	Betz Slimetrol RX41	16187	B-bromo-b-nitrostyrene (9.2%) Methylene bis(thiocyanate) (4.9%)	254	-	-	-	-

Table 2: Types and Volumes of Slimicides Used in Atlantic Canada

Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
Irving Pulp & Paper	-	-	-	-	-	-	-	-
Irving Tissue Company	Busan 52	12008	Potassium n-hydroxymethyl-n-methyldithiocarbamate (32%) Sodium salt of 2-mercaptobenzothiazole (8%)	10	-	-	-	-
Lake Utopia Paper	DiBac	16204	Sodium hypochlorite (10.8%)	-	-	3,009	Constantly to warm water chest	not used
	X-Cell 430	24963	Sodium bromide (40%)	-	-	3,200	Constantly to warm water chest	not used
	GAX-16	19099	Poly[oxyethylene(dimethyliminio) ethylene(dimethyliminio)ethylene dichloride] (15%)	-	-	30	not used	Constantly to glycol system (building heating)
	Acti-brom 1338	21678	Sodium bromide (40%)	-	2,868	-	-	-
	Metasol CB 210	18477	1,2-dibromo-2,4-dicyanobutane (10%)	-	11	-	-	-
	Betz-Dearborn Spectrum RX3605	16113	Bis(trichloromethyl)sulfone (20%) N-alkyl dimethyl benzyl ammonium chloride (15.2%)	1,056	-	-	-	-
St. Anne Nackawic Co. Ltd.	-	-	-	-	-	-	-	-
Smurfit-Stone Container (Canada) Inc.	Metasol 300	18211	Dissodium ethylenebis (dithiocarbamate) (15%) Sodium dimethyldithiocarbamate (15%)	-	3,000	5,700	Quasi-continuously (timer) to stock system prior to blending and paper machine	not used
UPM-Kymmene Miramichi Inc.	Busan 85	18619	Potassium dimethyldithiocarbamate (50%)	-	14,600	27,000	Constantly to water and stock	All incoming freshwater is treated (slimicide(s) used not identified)
	Busan 1009	19077	Methylene bis(thiocyanate) (10%) 2-(thiocyanomethylthio)benzothiazole (10%)	-	8,160	14,800	Constantly to water and stock	

Table 2: Types and Volumes of Slimicides Used in Atlantic Canada

Company	Product	PCP#	Active Ingredient (A.I.) and Percentage of A.I.	Annual Usage of A.I.s (kg)			Usage Areas	
				1986	1997	2000	Pulping Process	Other Facilities
	Busan 77	12004	Poly[oxyethylene(dimethyliminio) ethylene(dimethyliminio)ethylene dichloride] (60%)	-	3,960	2,400	Constantly to water and stock	
	Busan 1167	22577	Sodium bromide (40%)	-	2,080	6,400	Constantly to water and stock	
	Busan 1202	22931	Gluteraldehyde (50%)	-	-	5,000	Constantly to water and stock	
	Bulab 6044	24661	Sodium hypochlorite (10.8%)	-	-	31,320	Constantly to water and stock	
	Busan 90	12002	2-bromo-4'hydroxyacetophenone (30%)	-	6,150	-	-	
	Busan 1081	19002	2-methyl-4-isothiazolin-3-1 (0.95%) 5-chloro-2-methyl-4-isothiazolin-3-1 (2.84%)	-	167	-	-	
	Slime-trol RX-36	16113	Bis(trichloromethyl)sulfone (20%) N-alkyl dimethyl benzyl ammonium chloride (15.2%)	-	6,336	-	-	
	Slime-trol RX-68	17390	2-methyl-4-isothiazolin-3-1 (0.37%) 5-chloro-2-methyl-4-isothiazolin-3-1 (1.13%)	-	210	-	-	
	Slime-trol RX-96W	23963	2-bromo-2-nitropropane-1,2-diol (5.3%) N-alkyl dimethyl benzyl ammonium chloride (10%)	-	9,027	-	-	
	Sodium hypochlorite	13731	Sodium hypochlorite (~10%)	-	3,240	-	-	
NEW BRUNSWICK TOTAL				4,318	70,044	102,744	5 facilities	4 facilities
ATLANTIC REGION TOTAL				**17,713**	**75,690**	**121,561**	**10 facilities**	**6 facilities**

[1] PCP # - Pesticide Control Products #

[2] kg active ingredients were based on % active ingredients as obtained from the RIPP database (PMRA 2000) and outlined in Appendix A

Contrary to the reduction of mills using slimicides in the Region, the total amount of active ingredients increased steadily and dramatically from 1986 to 2000 (Figure 2). The data indicated that a total of 121,561 kg a.i. of registered slimicides were used in the Atlantic Region by pulp and paper facilities in the year 2000, with the majority of these slimicides (i.e. 102,744 kg or 84.5%) being used within New Brunswick, where most of the facilities are located. Amounts of registered slimicides (based on a.i.s) used in the Atlantic Region in 1986 and 1997 were 17,713 kg and 75,690 kg, respectively.

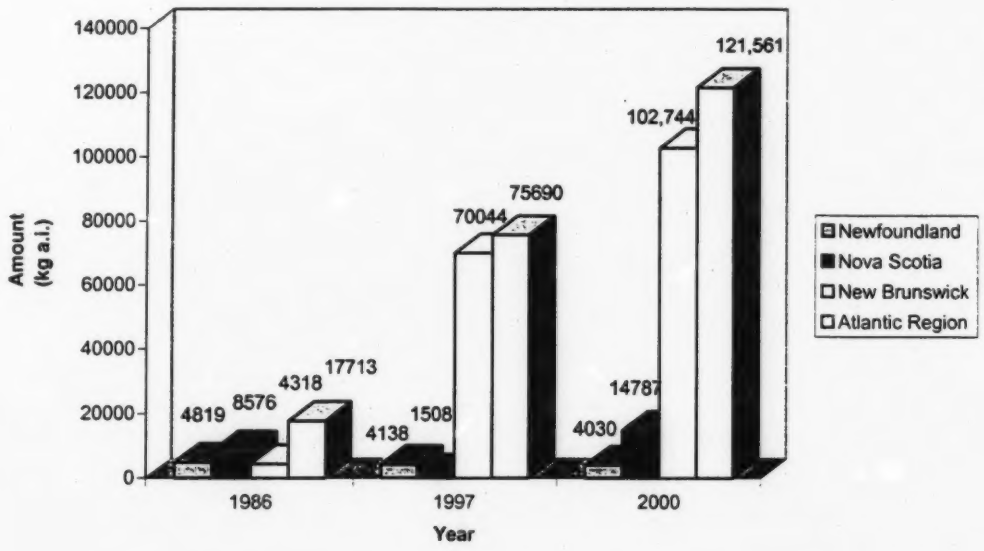
New Brunswick facilities accounted for 94.8% of the increase in use from 1986 to 2000, with an increase of 98,426 kg a.i. since 1986, and an increase of 71.29% or 32,700 kg a.i. between 1997 and 2000. Nova Scotia accounted for a 5.98% increase (6,211 kg a.i.) since 1986, with an increase of 28.95% (13,270 kg a.i.) between 1997 and 2000. Newfoundland facilities were responsible for a slight decrease in slimicides usage of 0.76% (1789 kg a.i.) since 1986, with a decrease of 0.24% (108 kg a.i.) between the years 1997 and 2000.

In New Brunswick, two facilities that did not report the use of registered slimicides in 1986, were using substantial quantities of slimicides in 2000, 5,700 kg a.i. and 86,920 kg a.i., respectively, and accounted for 89% of the increase in slimicide usage. The remaining three facilities in New Brunswick accounted for only 6% of the increase in slimicide usage. Thus, one of the four mills reporting an increase in slimicide usage since 1997 was responsible for 84.0% of the increase. It appears that the increase in use of slimicide is specific to certain pulp and paper facilities. Interestingly, when asked about changes in use pattern of slimicides, only three mills reported they believed slimicide use had increased at their facility since 1997.

Of the two New Brunswick mills using substantial quantities of slimicides, one mill reported that their slimicide use is based on mill production, which has increased in the past five years. The other mill reported that slimicide use had increased to combat water fleas in the fresh water and algae in the cooling towers. In addition, both of these mills have undergone several changes in ownership over the years, possibly impacting their mill practices. In general, the rates of usage of slimicides will change as a result of process changes as well as rates of production.

In Nova Scotia, two of the three mills using slimicides accounted for 64.3% and 33.1% of the increase in Nova Scotia while the third mill only accounted for 2.5% of the increase.

Figure 2: Amount of Registered Slimicides Used at Pulp and Paper Facilities in the Atlantic Region



3.1.3 Types of Slimicides Used

The number and type of registered slimicides used at pulp and paper facilities in Atlantic Region has varied over the years. Twelve slimicides were reported to be in use in 1986, 22 in 1997 and 17 in 2000. None of the slimicides used in 1986 were used in 2000. There were five slimicides common to both 1986 and 1997. Sixteen of the slimicides used in 1997 were not used in 1986, eight of which were first registered after 1986 and were thus not available to mills at the time of the 1986 survey. Seven slimicides used in 1986 were no longer used in 1997. Eight slimicides were used in both 1997 and 2000. Eight of the slimicides used in 1997 were no longer used in 2000, and nine new slimicides were used in 2000. These results indicate a shift towards newer slimicide products over time.

Of the five slimicides used both in 1986 and 1997, there were no apparent trends. Three of the slimicides (Nalcon 7648; Betz Slimetrol RX-68 and Betz-Dearborn Spectrum RX3605) showed increased annual usage with the amount of active ingredients being used increasing compared to the other two slimicides (Busan 52 and Metasol CB-210) which showed decreased annual usage. These changes in usage probably follow the shift towards the use of different types of slimicides.

In 2000, Busan 85, Busan 1009, Busan 1167, and Busan 1202, were reported to be used in more than one facility. All other 13 slimicides were only used in one facility in the Atlantic region.

Of the eight slimicides used both in 1997 and 2000, with the exception of Busan 77, usage increased from 1997 to 2000. For four of the slimicides, usage was significantly higher from 1997 to 2000 (Busan 85, Busan 1009, Busan 1202, and Metasol 300).

Figures 3 and 4 present the volumes of those slimicides used in both 1986 and 1997, and also for those slimicides used in both 1997 and 2000.

Figure 3: Slimicide Usage 1986-1997

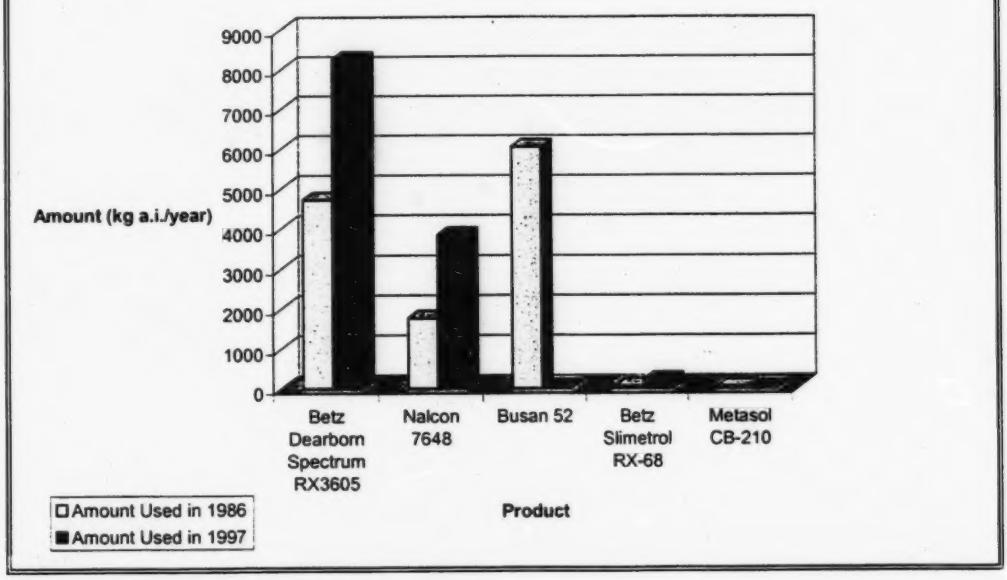


Figure 4: Slimicide Usage 1997-2000

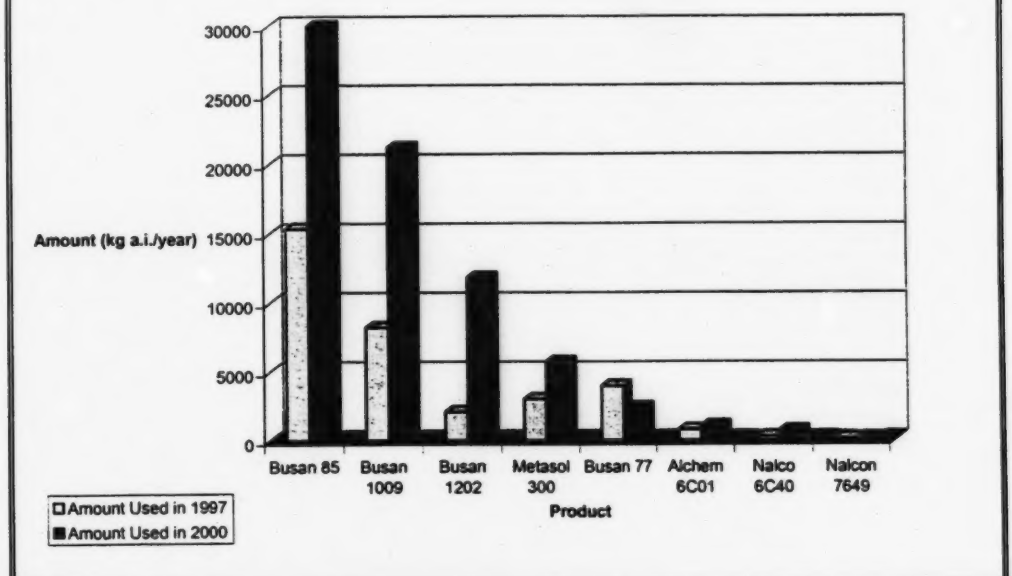
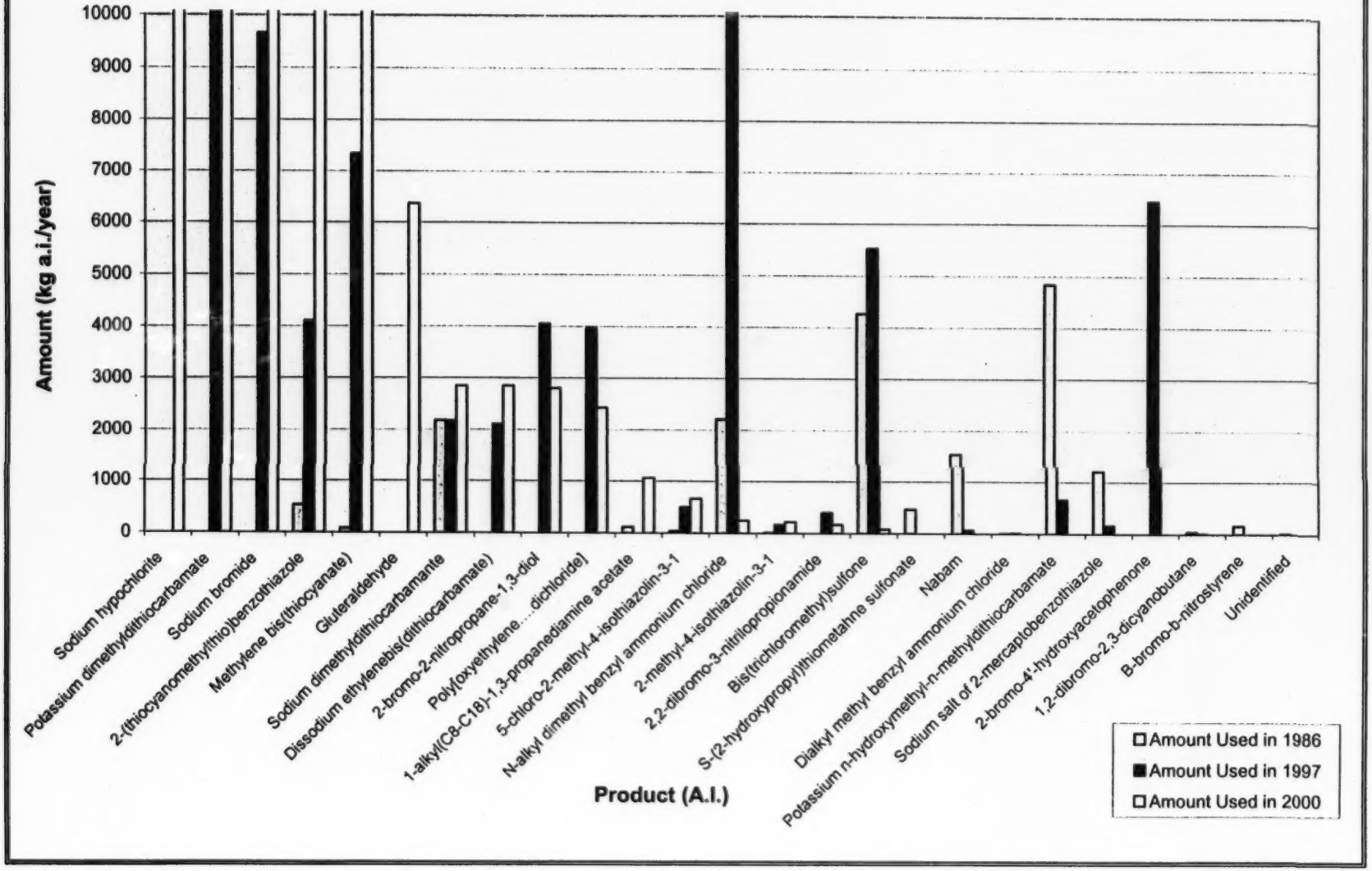


Figure 5 presents the amount of active ingredients (a.i.s) used in the years 1986, 1997 and 2000. Due to the low volumes for many of the slimicides, the scale was limited to 10,000 kg a.i./year. Any slimicide exceeding this value was considered to be a high volume use slimicide.

Figure 5: Slimicide A.I. Usage (1986-2000)



As presented in Figure 5, sixteen different active ingredients were being used in the Atlantic Region during the 2000 survey. Sodium hypochlorite was the most commonly used active ingredient with 35,625 kg used. Sodium hypochlorite is also used as a non-registered product to control biofouling; however, the total amounts used in this capacity were not always reported. The next most commonly used active ingredients were potassium dimethyldithiocarbamate (30,000 kg), sodium bromide (15,000 kg), 2-(thiocyanomethylthio)benzothiazole (10,600 kg) and methylene bis(thiocyanate) (10,600 kg). All other active ingredients were used in quantities less than 6,500 kg. These included: bis(trichloromethyl)sulfone; N-alkyl dimethyl benzyl ammonium chloride; gluteraldehyde; 1-alkyl(C8-C18)-1,3-propanediamine acetate; 2,2-dibromo-3-nitrolopropionamide; 2-bromo-2-nitropropane-1,3-diol; 2-methyl-4-isothiazolin-3-1; 5-chloro-2-methyl-4-isothiazolin-3-1; Poly[oxyethylene (dimethyliminio)ethylene(dimethyliminio)ethylene dichloride]; disodium ethylenebis (dithiocarbamate); and sodium dimethyldithiocarbamate.

3.1.4 Processes Where Registered Slimicides are Used

As presented in Table 2, the majority of registered slimicides were used in the pulping process while a few were used in other facility systems (e.g., cooling water systems; secondary treatment facility).

Ten of the eleven companies used slimicides in their pulping process in 2000. Of these, six introduced these products constantly, one introduced them at timed intervals, one used them once per day, one used them twice daily, and one indicated seasonal usage of slimicides from December to May (amounts used per day not specified). Slimicides were also applied at different stages of the pulping process; four companies stated that they applied it to the warm water tanks, three to the broke tank, two to the stock system, one to the retention aide, one to the storage tower, one to 'delaminated clay', one to the water used for pulping recycled pulp, and five applied it in more than one area.

Six of the eleven companies used slimicides in other facility systems in 2000. Of these, five reported to use slimicides constantly in at least one facility system, with two companies using slimicides seasonally in one facility system, and one company using slimicides on a batch basis for its paperboard operation. Slimicides were reported to being applied in the following operations; in the water supply used for mill operations (three companies), in the cooling tower (two companies), in white water loops of the paper machine (one company), added to water used for mixing/making down polymers (one company), to the glycol system (one company), and applied once per paperboard coating batch and applied to coating head (one company).

The results in Table 2 also indicate that several slimicides are applied in different mills in different facility processes. For example, sodium bromide is applied in the pulping process at three different mills, and in other facility systems (in the white water loops of the paper machine) in one facility. Thus, no one particular slimicide appears to be more appropriate than the others for controlling algae growth in the milling process or in other facility systems. According to Eriksson et al. (1995), certain slimicides can be grouped together based on such characteristics as their ability to control algae growth in neutral/alkaline or acidic conditions and/or processes. Thus, it appears that slimicides may be somewhat interchangeable in their applicability, thus if one were more toxic than another to humans and/or the environment, a less toxic slimicide could be substituted for a more toxic one.

3.1.5 Characteristics of Slimicide Application

In the 1997 survey, several questions were included to obtain some additional information about slimicide applications. All facilities reported that either records are kept for slimicide applications or there are inventories of slimicides used. Slimicide application equipment was reported to be calibrated on a regular basis either weekly, monthly or with each application for most facilities.

Five facilities (45%) reported that facility staff were responsible for the application of slimicides while contract applicators applied the slimicides at four other facilities (36%). In two facilities (18%), slimicide application was applied by a combination of facility staff and contract applicators. Only two facilities reported that facility staff had received any pesticide application training.

3.1.6 Environmental Releases of Slimicides

Eight facilities (72%) reported that some slimicide may reach the effluent treatment plant and one facility reported that slimicides could reach the mill sewers if there was a spill. None of the facilities reported that slimicides would reach untreated receiving waters, but none of the facilities monitored for slimicides in effluents or receiving waters. One facility reported that they monitor for chlorine residuals (chlorine being a common ingredient in several of the slimicides).

3.2 Other Methods and Products Used to Control Biofouling

In addition to registered slimicides, four companies indicated that they also use other methods and products to control fouling of pipes and corrosion of equipment in the 2000 survey. These methods included:

- use of stainless steel whenever possible;
- maintenance of a neutral pH in process effluents and waters (not identified how the pH is maintained);
- use of high temperatures;
- use of chlorine gas and sodium hypochlorite; and
- chemical cleanings (types and volumes not identified), boilouts.

Due to the descriptive nature of the survey question, no further information, such as quantities or location of use, was provided on these other methods used to control biofouling.

3.3 Ecotoxicity of Slimicides

Slimicides vary in toxicity. The ideal slimicide would be broad-spectrum (for a variety of bacteria, molds, yeasts, algae, and invertebrates), applicable over a broad temperature and pH range, economical, fast acting, free of organic solvents, odourless, be less toxic to non-target organisms, be readily biodegradable, and produce no toxic metabolites.

Table 3 presents the acute lethality to the water flea (*Daphnia magna*) and Rainbow trout (*Oncorhynchus mykiss*) for each of the high-volume slimicides (greater than 10,000 kg a.i. used in Atlantic Canada) that were in use during the 2000 survey (sodium hypochlorite, potassium dimethyldithiocarbamate, sodium bromide, 2-(thiocyanomethylthio)benzothiazole, and methylene bis(thiocyanate)). These species were selected because acute lethality testing to *Daphnia* and Rainbow trout is required as part of the Pulp and Paper Mill Effluent Regulations (see Regulatory Section, below for details). The results indicate significant variation in the toxicity of the different slimicides.

Table 3: Acute Lethality of High Volume Use Slimicides in Atlantic Canada (from most to least acutely toxic to aquatic organisms)

Product	Test Organism	LC_{50} [1] (mg/L)	Type of Study	Test Protocol	Reference
2-(thiocyano methylthio) benzothiazole	*Oncorhynchus mykiss* (Rainbow trout)	0.021	96 hour flow through bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
		0.029		EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
		0.045	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
			96 hour static bioassay		
Methylene bis(thiocyanate)	*Daphnia magna*	0.031	21 day static bioassay	OECD and Dutch Standardization Organization	Maas-Diepeveen, J.L and C. J. Van Leeuwen, 1988
		0.073	48 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000.
	Oncorhynchus mykiss (Rainbow trout)	0.084	14 day renewal bioassay	OECD and Dutch Standardization Organization	Maas-Diepeveen, J.L. and C. J. Van Leeuwen, 1988 (all three studies)
		0.065	60 day renewal bioassay		
		0.059	60 day renewal bioassay		
		0.089	96 hour static bioassay	EPA/600/4-90/027F	Office of Pesticide Programs, 2000
		0.24	96 hour static bioassay	EPA/600/4-90/027F	Office of Pesticide Programs, 2000
Potassium dimethyl dithiocarbamate	*Oncorhynchus mykiss* (Rainbow trout)	0.36	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000.
Sodium hypochlorite	*Daphnia magna*	2.1	96 hour static bioassay	ASTM Standard E 729-80	Ewell, W. S. et. Al., 1986
	Oncorhynchus mykiss (Rainbow trout)	1.35	24 hour static bioassay		
		4.18	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
		1.94	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
		0.2	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000
Sodium bromide	*Daphnia magna*	5171	24 hour renewal bioassay	German article translation not available at time of writing	Kuhn, R. 1988.
		91	21 day renewal bioassay		Kuhn, R. 1988.
	Oncorhynchus mykiss (Rainbow trout)	>1000	96 hour static bioassay	EPA/600/4- 90/027F	Office of Pesticide Programs. 2000.

Note:
[1] Defined as the concentration required to kill 50% of the test population in a laboratory experiment

Based on the acute lethal toxicity values, sodium bromide appears to have the lowest toxicity to *Daphnia magna* and/or Rainbow trout, followed by sodium hypochlorite, potassium dimethyldithiocarbamate, 2-(thiocyanomethylthio)benzothiazole (TCMTB) and methylene bis(thiocyanate) (MBT).

In addition to the acute toxicity studies, which are typically acute tests and the measured effect focuses solely on mortality, there are other types of tests, including longer-term studies (chronic studies) and/or those which assess non-mortality effects. Table 4 presents a variety of aquatic toxicity tests for the same five high volume use slimicides as presented in Table 3.

Table 4: Sublethal Toxicity of High Volume Use Slimicides in Atlantic Canada (From the most to the least toxic to aquatic organisms)

Product	Test Organism	Concentration (mg/L)	Effect	Study	Reference
2-(thiocyano methylthio) benzothiazole (TCMTB)	*Daphnia magna*	0.02-0.026	EC50 (intoxication)	48 hour flow-through bioassay	Office of Pesticide Programs, 2000
	Daphnia magna	0.013-0.036	EC50 (intoxication)	48 hour static bioassay	Office of Pesticide Programs, 2000
	Salmonidae (of the Trout family - not specified)	0.01	NOEC (physiological effects)	96 hour flow-through bioassay	Kruzynski, G.M. and I.K. Birtwell, 1991
Methylene bis(thiocyanate) (MBT)	*Chlorella pyrenoidosa* (green algae)	0.027-0.067	EC50 (growth effects)	96 hour static bioassay	Maas-Diepeveen, J.L. and C. J. Van Leeuwen, 1988
	Daphnia magna	0.033-0.044	EC50 (intoxication)	48 hour static bioassay	Office of Pesticide Programs, 2000
	Oncorhynchus mykiss (Rainbow trout)	0.051-0.068	EC50 (growth)	60 day renewal bioassay	Maas-Diepeveen, J.L. and C. J. Van Leeuwen, 1988
Sodium hypochlorite	Freshwater algae	0.0021	Lowest observed effect concentration (LOEC) (biochemical effects)	28 day flow through bioassay	Pratt, J. R. et. Al., 1988
	Freshwater algae	0.0036	Maximum acceptable concentration (MAC) (decrease in enzyme production)	28 day flow through bioassay	Pratt, J. R. et. Al., 1988
	Freshwater algae	0.05	MAC (decrease in population)	28 day flow through bioassay	Pratt, J. R. et. Al., 1988
	Daphnia magna	0.04-2.6	Effective concentration wherein 50% of the test population (EC50) experienced some form of intoxication	48 hour static bioassay	Office of Pesticide Programs, 2000
	Menidia beryllina (Inland silverside)	0.087	NOEC (decrease in growth)	7 day flow-through bioassay	Fisher, D. J., et. Al., 1994
	Menidia beryllina (Inland silverside)	0.18-0.186	NOEC (decrease in growth)	7 day pulse (intermittent or fluctuating dosing)	Fisher, D. J., et. Al., 1994

Table 4: Sublethal Toxicity of High Volume Use Slimicides in Atlantic Canada (From the most to the least toxic to aquatic organisms)

Product	Test Organism	Concentration (mg/L)	Effect	Study	Reference
				bioassay	
Potassium dimethyldithio carbamate	*Acanthamoeba hatchetti* (amoeba)	0.5-62	LOEC (decrease in population)	24 hour static bioassay	Srikanth, S. and S. G. Berk, 1993
	Daphnia magna	0.29-0.39	EC50 (intoxication)	48 hour static bioassay	Office of Pesticide Programs, 2000
Sodium bromide	*Daphnia magna*	91	NOEC (behaviour effects)	21 day renewal bioassay	Kuhn, R. 1988
	Daphnia magna	43	Effective concentration wherein 10% of the test population experienced some form of growth effect	16 day renewal bioassay	Deneer, J. W., W. Seinen, and J. L. M. Hermens, 1988
	Daphnia magna	20.8	EC50 (decreased reproduction)	21 day renewal bioassay	Guilhermino, L. et. Al., 1999
	Daphnia magna	19	LOEC (reproductive effects)	21 day renewal bioassay	Guilhermino, L. et. Al., 1994
	Daphnia magna	2.8	NOEC (growth effects)	16 day renewal bioassay	Deneer, J. W., W. Seinen, and J.L.M. Hermens, 1988
	Poecilia reticulata (guppy)	140	EC50 (reproductive effects)	124 day renewal bioassay	Canton, et. Al., 1983
	Poecilia reticulata (guppy)	7.8	NOEC (reproductive effects)	124 hour renewal bioassay	Canton, et. Al., 1983
	Poecilia reticulata (guppy)	32	NOEC (behaviour effects)	1-3 month renewal bioassay	Wester, P.W., J. H. Canton, and J.A.M. Dormans, 1988

As indicated in Table 4, adverse effects to aquatic receptors are expected to be lowest due to exposure to sodium bromide, followed by potassium dimethyldithiocarbamate, sodium hypochlorite, methylene bis(thiocyanate), and 2-(thiocyanomethylthio)benzothiazole.

3.3.1 Sodium Bromide

Sodium bromide itself has no pesticidal activity (USEPA, 1993). It dissociates in water to sodium and bromide ions. Activators such as chlorine and sodium hypochlorite react with bromine to form hypobromous acid, which is the actual pesticide (USEPA, 1993). If hypobromous acid passes through a heat exchange unit, it is converted back to bromide ion and water.

The USEPA modeled hypobromous acid in aquatic systems, and calculated environmental concentrations for both 'high exposure cases' and at 'typical sites' (USEPA, 1993). The worst-case for all use sites tested was 450 parts per billion (ppb) at the point of discharge, with typical sites ranging from 0.38 to 0.75 ppb. In an aquatic residue monitoring study of power plants on the Potomac River in Maryland, U.S.A., hypobromous acid was measured at the point of discharge that exceeded

concentrations of concern for aquatic species, with residual levels detected 80 metres downstream, and non-detectable residual levels greater than 80 metres downstream. The concentrations identified in the Potomac were comparable to the modeled high exposure case. However, modeling results for typical sites were well below levels of concern for fish and invertebrates, indicating that sodium bromide could be used at typical sites without impact "most of the time" (USEPA, 1993). The discharge of hypobromous acid is controlled by a permit program in the U.S. by the EPA Office of Water, which acts to control volumes discharged in effluent. The USEPA concluded that the use of currently registered pesticides containing sodium bromide were not expected to pose unreasonable risks or adverse effects to humans or the environment (USEPA, 1993).

3.3.2 Potassium Dimethyldithiocarbamate

Very little physical and chemical information was identified for potassium dimethyldithiocarbamate. Based on HSDB (2002), dimethyldithiocarbamates tend to be soluble in water, sorb moderately to soil and/or sediment, have a negligible vapour pressure (indicating negligible volatilization from water or soil surfaces), and tend to be stable in neutral solutions but decompose readily under acidic conditions to form carbon disulfide and dimethylamine. If released to air as an aerosol, dimethyldithiocarbamates are expected to be removed from the atmosphere via wet or dry deposition. Based on Kow values for several dimethyldithiocarbamates (i.e. Ziram and Ferbam), these substances are expected to have a low bioaccumulation potential in aquatic organisms. The USEPA is currently involved in the assessment of dithiocarbamate pesticides and has not provided any conclusions regarding its reregistration (USEPA, 2001).

3.3.3 Sodium Hypochlorite

In freshwater, hypochlorites break down rapidly into non-toxic compounds when exposed to sunlight. Solubility was identified as 100% in water (MSDS, 2001). In seawater, chlorine levels decline rapidly, however, hypobromite (which is acutely toxic to aquatic organisms) is formed. Therefore, if released to the marine environment, sodium hypochlorite may be acutely toxic to aquatic organisms. The USEPA completed a Reregistration Eligibility Document (RED) in 1991 which concluded that all pesticide products containing sodium hypochlorite were eligible for reregistration (USEPA, 1991).

3.3.4 2-Thiocyano methyl thio benzothiazole (TCMTB)

In a risk assessment of slimicides, Eriksson et al. (1995) found that TCMTB was one of the slimicides in the study which had the highest level of environmental risk. It has a low vapour pressure, moderate water solubility, low volatility, with a high Koc, indicating that it is expected to sorb strongly to soil and/or sediment (Eriksson, et. al., 1995). TCMTB is assumed to be environmentally stable and is expected to biodegrade slowly. In addition, it is also considered to have a high potential for bioaccumulation in aquatic organisms (Eriksson, et. al., 1995). This active ingredient is found in Busan 1009 which had substantial usage (21,200 kg) in the year 2000. Eriksson et al (1995) stated that the benefits of TCMTB as a slimicide did not exceed it risks to aquatic organisms and recommended that its use be phased out within one year. It has not been approved for use in Sweden since 1996.

3.3.5 Methylene bis(thiocyanate) (MBT)

In a risk assessment of MBT, Milanova and Sithole (1997) found that MBT is unlikely to accumulate in the environment due to its experimental half-life values in aquatic systems of between 4 and 28 hours. Degradation, however, was affected by pH and initial MBT concentration in the initial effluent. Therefore, although it is not expected to persist in the environment, if conditions in mills are not sufficient for degradation, acute toxicity of the final effluents may result (Milanova and Sithole, 1997).

The USEPA completed a RED in 1997 which concluded that products containing methylene bis(thiocyanate) are eligible for reregistration in pulp/paper mill water systems (USEPA, 1997).

Acute and subacute toxicity studies for the remaining eleven lower volume use slimicides are presented in Appendix B. As presented in Appendix B, several of these other slimicides are considered to be moderately to highly toxic to aquatic and/or terrestrial organisms.

3.3.6 Degradation Products of Active Ingredients

In addition to an understanding of the toxicity of the parent compound, it is also important to understand the degradation compounds formed when slimicides are mixed with water and/or other chemicals used in the various facility processes in order to assess potential toxicity to organisms in the receiving environment. An assessment of degradation compounds was beyond the scope of this report, however, of the five high volume use active ingredients in Atlantic Canada, Table 5 presents the potential degradation products and associated aquatic toxicity (where available).

Table 5: Potential Degradation Compounds of Active Ingredients of High Volume Use Slimicides in Atlantic Canada

Active Ingredient	Potential Degradation Compound(s)	Additional Information
Sodium hypochlorite	Trihalomethanes may be produced due to the degradation of sodium hypochlorite In seawater, chlorine levels decline rapidly, and hypobromite can be formed (USEPA, 1991) In freshwater, sodium hypochlorite rapidly breaks down to non-toxic compounds when exposed to sunlight (USEPA, 1991)	Hypobromite is acutely toxic to aquatic organisms (USEPA, 1991)
Potassium dimethyl dithiocarbamate	Dimethyldithiocarbamate ions biodegrade in soil, releasing carbon disulfide and forming dimethylamine and/or dithiocarbamate (HSDB, 2002)	
Sodium bromide	Sodium bromide dissociates in water to sodium and bromide ions Chlorine and/or sodium hypochlorite reacts with bromine to create hypobromous acid Hypobromous acid if passed through a heat exchange unit will convert back to bromide ion and water (USEPA, 1993)	Sodium bromide as hypobromous acid is highly toxic to freshwater fish, aquatic invertebrates and estuarine and marine organisms (USEPA, 1993)
2-(thiocyano methylthio) benzothiazole	Aerobic degradation products include mercaptobenzothiazole, 2-(methylthio)benzothiazole (MTBT), and/or 2-2-dithiobisbenzothiazole (MBTS) Photolysis degradation products include benzothiazole and/or MBTS Hydrolysis degradation product was primarily MBTS (Eriksson, et. al., 1995)	MBTS - moderate to high toxicity to algae 96 hour EC50 (*Selenastrum capricornutum*) - 0.6-0.7 mg/L MBTS - moderate toxicity to Daphnia and fish 48 hour LC50 (*Daphnia magna*) - 82 mg/L 96 hour LC50 (*Oncorhynchus mykiss*) - 66 mg/L (Eriksson, et. al., 1995)
Methylene bis(thiocyanate)	The major hydrolysate observed was the thiocyanate ion (SCN^-) (USEPA, 1997) The thiocyanate ion may degrade to cyanide, cyanide and formaldehyde are potential degradates of MBT (USEPA, 1997)	If released into water (neutral pH), methylene thiocyanate is expected to hydrolyze rapidly (HSDB, 2002) Very highly toxic to aquatic invertebrates on an acute basis; chronic effects were observed in freshwater fish and aquatic invertebrates (USEPA, 1997) Dissipates within a few hours at a neutral pH (HSDB, 2002)

3.4 Effluent Toxicity Testing Requirements

Pulp and paper mill effluent is regulated under the *Pulp and Paper Effluent Regulations,* SOR/92-269, under the *Fisheries Act.* The regulations require monitoring of effluent to ensure that it is not acutely lethal to Rainbow trout during 96 hour exposures of 100% effluent. In addition, the *Regulations* also require pulp mills to conduct Environmental Effects Monitoring, which involves documenting the longer term effects of the pulp mill effluent on fish, fish habitat and the use of fisheries resources.

Pulp and paper mills are required to monitor their effluent for sublethal toxicity to three different species of organisms (salt water species for marine water receiving environments, freshwater species for freshwater receiving environments) twice per year. For discharge to the marine environment, the three sub-lethal toxicity tests examine the following: 1) sea urchin fertilization; 2) Inland silverside (*Menidia beryllina*) growth; and red algae (*Champia parvula*) reproduction. In addition, pulp and paper mills are required to test monthly for acute lethality to Rainbow trout and weekly to *Daphnia magna.* Pulp and paper mills are also required to conduct daily monitoring for total suspended solids (TSS) and test for biochemical oxygen demand (BOD) at a minimum of three times per week. Conductivity and pH are tested on a continuous basis (MT Grant, personal communication; Kay Kim, personal communication).

There are no requirements for monitoring of registered slimicides or their active ingredients in pulp and paper mill effluents. In the survey results, none of the mills indicated that they monitor their effluents for slimicides and/or their active ingredients. Since several of the active ingredients may be toxic to aquatic life in low concentrations, it may be useful to monitor effluent for the presence of slimicides and their by-products (if known). Therefore, it would be useful to monitor for concentrations of slimicides in effluents and receiving environments to determine whether exceedences of toxicity and environmental impact measured by the currently required monitoring is caused by slimicide discharges.

4. SUMMARY AND RECOMMENDATIONS

According to the data collected, slimicide use patterns have changed substantially between 1986 and 2000. Although the number of pulping facilities in Atlantic Canada using slimicides have decreased from 1986 to 2000, total slimicide usage in the Region within that sector has increased dramatically, rising over six-fold in those years. The majority of the increase occurred in facilities in New Brunswick.

None of the registered slimicides used in 1986 were used in 2000. The five highest volume slimicide active ingredients used in Atlantic Canada in 2000 were sodium hypochlorite, potassium dimethyldithiocarbamate, sodium bromide, 2-(thiocyanomethylthio)benzothiazole, and methylene bis(thiocyanate). Sixteen other active ingredients were also used in lower volumes in Atlantic Canada in 2000. The increase in volumes used and the transition to some products which have a greater hazard than older products likely represents a substantial increase in environmental risk associated with their use.

Although some records are kept of applications and volumes of slimicides used, improvements in record keeping are recommended specifically.

Eight of eleven facilities reported that slimicides may reach effluent treatment plants, and none of the facilities indicated that they monitor effluent or receiving water for the presence of slimicides. Due to this lack of data and the varying toxicities of these slimicides and their degradation products, it is currently not known what affect slimicides may be having on environmental quality in the receiving environments. Therefore, data should be collected in order to determine the presence and concentration of any slimicides being discharged by pulping facilities in Atlantic Canada that currently use slimicides.

This data collection would be most important where facilities fail the acute and/or chronic effluent toxicity testing as required under the *Pulp and Paper Mill Effluent Regulations*, in order to determine whether these products are present and may be contributing to the test failures.

Based on the persistence, bioaccumulation potential and highly toxic nature of TCMTB (Busan 1009) to aquatic organisms, its use as a registered slimicide in Sweden was phased out in 1996. It is recommended that a high priority be placed on more detailed environmental investigations at those facilities using this product to determine whether environmental impacts in the Canadian environment are acceptable.

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APPENDIX A

SLIMICIDE USE AT PULP AND PAPER FACILITIES IN THE ATLANTIC REGION SURVEY QUESTIONNAIRE

Slimicide Use at Pulp and Paper Facilities in the Atlantic Region

Facility Name:	
Address:	
Contact name and Title:	

Section I: Slimicide Use in Pulping Process

If slimicides and/or other biocides are not used in the pulping process, skip to **Section II**. If slimicides and/or other biocides are used, please complete the following:

Product Name	Active Ingredient	Pesticide Control Product Number (PCP#)	Supplier/ Contractor	Period of Use (current/ historical)	Annual average consumption (kg) (if currently used)

1) How often are slimicides applied (constant basis, monthly, yearly)?

2) Where in the process are the slimicides applied?

3) In general, over the last 5 years, has your use of slimicides, in the pulping process, on an annual basis changed? _____ Increased; _____ Decreased _____ Remained the same. If there has been a change, please describe the reasons for the change in use patterns.

Section II: Use of Slimicides and/or Other Biocides in Other Facility Systems

If slimicides and/or other biocides are not used in other facility systems (e.g., cooling water), skip to **Section III**. If slimicides and/or other biocides are used, please complete the following:

Product Name	Active Ingredient	Pesticide Control Product Number (PCP#)	Supplier/ Contractor	Period of Use (current/ historical)	Annual average consumption (kg) (if currently used)

1) In what facility systems are the slimicides and/or other biocides applied? (e.g. cooling systems, etc.)

2) How often are slimicides and/or other biocides applied (constant basis, monthly, yearly)?

3) In general, over the last 5 years, has your use of slimicides, in other facility systems, on an annual basis changed? _____ Increased; _____ Decreased _____ Remained the same. If there has been a change, please describe the reasons for the change in use patterns.

Section III: Other Methods to Control Biofouling

In addition to slimicides, does your company use other methods to control biofouling of pipes and/or corrosion of equipment? ____ No _____Yes If yes, please complete the following questions:

1) What methods or products, other than or in addition to slimicides, are used to control biofouling of pipes and/or corrosion of equipment? Please describe, providing name, PCP#, annual consumption, if appropriate:

2) How often are these other methods or products used (constant basis, monthly, yearly)?

3) Where in the process or the facility system are these alternate methods applied?

APPENDIX B

TOXICITY OF LOWER VOLUME USE SLIMICIDES (2000)

Table B1: Toxicity Associated with Lower Volume Use Slimicides in Atlantic Canada

Product	A.I.(%)	Test Species	Concentration	Effect/Type of Study	Reference
Bis(thrichloromethyl)	100%	Rainbow trout	0.1 ppm	24 hour LC50	Milanova, 1997
sulfone	100%	Rainbow trout	0.02 ppm	96 hour LC50	Milanova, 1997
	technical grade	Rat (male)	545 mg/kg	Oral LD50	USEPA, 1995
	technical grade	Rat (female)	535 mg/kg	Oral LD50	USEPA, 1995
	technical grade	Rabbit	>5000 mg/kg	Dermal LD50	USEPA, 1995
	technical grade	Rat	0.04 mg/L	Inhalation LC50	USEPA, 1995
	technical grade	Rat	50 mg/kg	NOAEL (body temperature and motor activity)	USEPA, 1995
	technical grade	Rat	5 mg/kg-bw/day	NOAEL (hematological, and dermal irritation)	USEPA, 1995
	technical grade	Rat	2 mg/kg-bw/day	NOAEL (maternal toxicity - decreased body wt)	USEPA, 1995
	technical grade	Rat	10 mg/kg-bw/day	NOAEL (teratogenic effects)	USEPA, 1995
	technical grade	Rabbit	20 mg/kg-bw/day	NOAEL (maternal toxicity - decreased body wt)	USEPA, 1995
	technical grade	Rabbit	45 mg/kg-bw/day	NOAEL (developmental toxicity)	USEPA, 1995
	technical grade	Mallard duck	>2,250 mg/kg	Acute LD 50	USEPA, 1995
	technical grade	Mallard duck	>5620 mg/kg	Subacute LD50	USEPA, 1995
	technical grade	Northern Bobwhite Quail	>5000 mg/kg	Subacute LD50	USEPA, 1995
	technical grade	Rainbow trout	0.29 mg/kg	Acute LD 50	USEPA, 1995
	technical grade	Bluegill sunfish	0.58 mg/kg	Acute LD 50	USEPA, 1995
	technical grade	Daphnia magna	0.173 mg/kg	Acute EC50	USEPA, 1995
	99%	Sheepshead minnow	0.4 mg/L	Acute LC50	USEPA, 1995
	99.90%	Quahog clam (embryo-larvae)	0.0092 mg/L	Acute LC50	USEPA, 1995
N-alkyl dimethyl benzyl	100.00%	Daphnia magna	0.02 mg/L	Acute LC50	Dobbs, 1995
ammonium chloride		Mysid shrimp	0.08 mg/L	Acute LC50	Dobbs, 1995
		Menidia beryllina	0.31 mg/L	Acute LC50	Dobbs, 1995
		Fathead minnow	0.36 mg/L	Acute LC50	Dobbs, 1995
		Sheepshead minnow	0.88 mg/L	Acute LC50	Dobbs, 1995
		Rainbow trout	1.01 mg/L	Acute LC50	Dobbs, 1995
Gluteraldehyde	100%	Coho salmon	3 mg/L	96 hour flow through LC50	Leung, 2001
	100%	Daphnia magna	5 mg/L	48 hour static LC50	Leung, 2001
	100%	Fathead minnow	5.4 mg/L	96 hour static LC50	Leung, 2001
	100%	Fathead minnow	6 mg/L	96 hour static LC50	Leung, 2001
	100%	Bluegill sunfish	9.6 mg/L	96 hour static LC50	Leung, 2001
	100%	Bluegill sunfish	11 mg/L	96 hour static LC50	Leung, 2001
	100%	Rainbow trout	11 mg/L	96 hour static LC50	Leung, 2001

Table B1: Toxicity Associated with Lower Volume Use Slimicides in Atlantic Canada

Product	A.I.(%)	Test Species	Concentration	Effect/Type of Study	Reference
	100%	Rainbow trout	12 mg/L	96 hour static LC50	Leung, 2001
	100%	Calanoid copepod	0.11 mg/L	48 hour static LC50	Leung, 2001
	100%	Mussel	0.2 mg/L	5 day flow-through LC50	Leung, 2001
	100%	Mysid shrimp	7.1 mg/L	96 hour flow through LC50	Leung, 2001
	100%	Sheepshead minnow	32 mg/L	96 hour static LC50	Leung, 2001
	50%	Bobwhite quail	5000 mg/kg	5 day LC50	Leung, 2001
	50%	Bobwhite quail	2320 mg/kg	NOEC	Leung, 2001
	50%	Mallard duck	1075 mg/kg	NOEC	Leung, 2001
	50%	Mallard duck	408	LD50	Leung, 2001
	25%	Mallard duck	466	LD50	Leung, 2001
	50%	Rat	527 mg/kg	LD50	Eriksson, 1995
	50%	Rat	50 mg/kg	NOAEL (oral exposure)	Eriksson, 1995
	50%	Dog	50 mg/kg	NOAEL (oral exposure)	Eriksson, 1995
	50%	Mouse	100 mg/kg	NOAEL (oral exposure)	Eriksson, 1995
	50%	Rabbit	15 mg/kg	NOAEL (teratogenic effects)	Eriksson, 1995
	50%	Rat	68 mg/kg	NOAEL (teratogenic effects)	Eriksson, 1995
	50%	Green algae	0.085 mg/L	72 hour EC50	Eriksson, 1995
	50%	Green algae	0.31 mg/L	NOEC	Eriksson, 1995
	50%	Daphnia magna	16 mg/L	48 hour EC50	Eriksson, 1995
	50%	Bluegill sunfish	11-12 mg/L	96 hour LC50	Eriksson, 1995
	50%	Rainbow trout	11-12 mg/L	96 hour LC50	Eriksson, 1995
	50%	Sheepshead minnow	32 mg/L	96 hour LC50	Eriksson, 1995
	50%	Daphnia magna	2.1 mg/L	NOEC (teratogenic effects)	Eriksson, 1995
	50%	American oyster larvae	0.55 mg/L	48 hour LC50	Eriksson, 1995
	50%	Green crab	465 mg/L	LC50	Eriksson, 1995
	50%	Grass shrimp	41 mg/L	LC50	Eriksson, 1995
1-alkyl(C8-C18)-1,3-propanediamine acetate	No information			PMRA was contacted for information regarding this slimicide, however, no information was provided. The USEPA has listed this substance on its Pesticide Data Submitters List, however, no toxicity information was identified.	
2,2-dibromo-3-nitrolpropionamide	95%	Rat (male)	235 mg/kg	Oral LD50	USEPA, 1994
	95%	Rat (female)	178 mg/kg	Oral LD50	USEPA, 1994
	95%	Rabbit	>2 g/kg	Dermal LD50	USEPA, 1994
	95%	Rat	0.32 mg/L	Inhalation LC50	USEPA, 1994
	95%	Rat	0.05 mg/kg-bw/day	NOAEL (ingestion)	USEPA, 1994

Table B1: Toxicity Associated with Lower Volume Use Slimicides in Atlantic Canada

Product	A.I.(%)	Test Species	Concentration	Effect/Type of Study	Reference
	95%	Rat	309 mg/kg-bw/day	NOAEL (90 day study - dermal contact)	USEPA, 1994
	95%	Rat	30 mg/kg-bw/day	NOAEL (developmental toxicity)	USEPA, 1994
	95%	Mallard duck	150-534 mg/kg	Oral LD50	USEPA, 1994
	95%	Bobwhite quail	150-534 mg/kg	Oral LD50	USEPA, 1994
	technical grade	Green algae	0.3 mg/L	96 hour static EC50	
	100%	Bluegill sunfish	2.3 mg/L	96 hour static LC50	USEPA, 1994
	technical grade	Bluegill sunfish	1.3 mg/L	96 hour static LC50	USEPA, 1994
	technical grade	Rainbow trout	1.0 mg/L	96 hour static LC50	USEPA, 1994
	100%	Rainbow trout	2.3 mg/L	96 hour static LC50	USEPA, 1994
	100%	Black bullhead	1.4 mg/L	96 hour static LC50	Klaine, 1996
	100%	Channel catfish	0.88	96 hour static LC50	Klaine, 1996
	99.10%	Fathead minnow	1.8 mg/L	96 hour LC50	USEPA, 1994
	technical grade	Zebrafish	1.08 mg/L	96 hour static LC50	
	99.50%	Sheepshead minnow	3.4 mg/L	96 hour flow-through LC50	USEPA, 1994
	95%	Sheepshead minnow	1.7 mg/L	96 hour static LC50	USEPA, 1994
	95%	Daphnia magna	0.9 mg/L	48 hour static EC50	USEPA, 1994
	100%	Daphnia magna	0.86 mg/L	static EC50	USEPA, 1994
	technical grade	Daphnia magna	0.5 mg/L	Static 48 hour immobilization endpoint	Klaine, 1996
	99.50%	Mysid shrimp	0.72 mg/L	Flow-through bioassay	USEPA, 1994
	99.50%	Eastern oyster	<0.07 mg/L	Flow-through bioassay	USEPA, 1994
	95%	Eastern oyster larvae	0.74 mg/L	48 hour static LC50	USEPA, 1994
	95%	Pink shrimp	2.4 mg/L	96 hour static LC50	USEPA, 1994
	95%	Fiddler crab	13.9 mg/L	96 hour static LC50	USEPA, 1994
	98%	Rainbow trout	>0.47 <0.98 mg/L	NOAEL	USEPA, 1994
	98%	Daphnia magna	<0.02 mg/L	NOAEL	USEPA, 1994
2-bromo-2-nitropropane-1,3-diol	14-18%	Rat	254-342 mg/kg	Oral LD50	Eriksson, 1995
	14-18%	Rat	>1600 mg/kg	Dermal LD50 (in water)	Eriksson, 1995
	14-18%	Rat	64-60 mg/kg	Dermal LD50 (in acetone)	Eriksson, 1995
	14-18%	Rat	200 mg/kg	Subcutaneous LD50	Eriksson, 1995
	14-18%	Mouse	0.038-0.089 mg/dm3	NOAEL (inhalation irritant effects)	
	14-18%	Rat	20 mg/kg-bw/day	NOAEL (respiratory difficulties, internal swelling, irritative lesions)	Eriksson, 1995
	14-18%	Rat	<25 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	14-18%	Rabbit	40 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	40-50%	Green algae	0.02 mg/L	72 hour EC50	Eriksson, 1995
	40-50%	Green algae	0.01 mg/L	NOEC	Eriksson, 1995
	40-50%	Bluegill sunfish	35-68 mg/L	96 hour LC50	Eriksson, 1995

Table B1: Toxicity Associated with Lower Volume Use Slimicides in Atlantic Canada

Product	A.I.(%)	Test Species	Concentration	Effect/Type of Study	Reference
	40-50%	Rainbow trout	35-68 mg/L	96 hour LC50	Eriksson, 1995
	40-50%	Sheepshead minnow	35-68 mg/L	96 hour LC50	Eriksson, 1995
	40-50%	Daphnia magna	1.4 mg/L	48 hour LC50	Eriksson, 1995
	40-50%	Daphnia magna	0.27 mg/L	NOEC (teratogenic effects)	Eriksson, 1995
	40-50%	Mysid shrimp	5.9 mg/L	96 hour LC50	Eriksson, 1995
	40-50%	Brown shrimp	121 mg/L	96 hour LC50	Eriksson, 1995
	40-50%	Oyster larvae	1.7 mg/L	48 hour LC50	Eriksson, 1995
	40-50%	Oyster larvae	0.69 mg/L	48 hour LC50 (abnormal larvae)	Eriksson, 1995
2-methyl-4-isothiazolin-3-one	technical grade	Rat	105 mg/kg	Oral LD50	USEPA, 1998
	technical grade	Rabbit	200 mg/kg	Dermal LD50	USEPA, 1998
and	technical grade	Rat	0.33 mg/kg	Inahalation LC50	USEPA, 1998
5-chloro-2-methyl-4-	100%	Rat	457 mg/kg	Oral LD50	Eriksson, 1995
Isothiazolin-3-one	100%	Rabbit	66 mg/kg	Dermal LD50	Eriksson, 1995
	13.90%	Rat	8 mg/kg-bw/day	NOAEL (oral exposure)	Eriksson, 1995
	13.90%	Rat	0.00034 mg/dm3	NOAEL (3 month inhalation exposure)	Eriksson, 1995
	13.90%	Rabbit	1.5 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	13.90%	Rat	>100 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	14.17%	Mallard duck	717 mg/kg-bw/day	LC50	USEPA, 1998
	14.17%	Bobwhite quail	2200 mg/kg-bw/day	LC50	USEPA, 1998
	Not stated	Skeletonema costatum	0.01 mg/L	72 hour EC50	Eriksson, 1995
	Not stated	Skeletonema costatum	<0.01 mg/L	NOEC	Eriksson, 1995
	Not stated	Daphnia magna	0.18 mg/L	48 hour EC50	Eriksson, 1995
	Not stated	Daphnia magna	0.1 mg/L	NOEC (21 day for teratogenic effects)	Eriksson, 1995
	Not stated	Zebrafish	0.27 mg/L	96 hour LC50	Eriksson, 1995
	Not stated	Zebrafish	0.084 mg/L	NOEC	Eriksson, 1995
	Not stated	Sheepshead minnow	0.3 mg/L	96 hour LC50	Eriksson, 1995
	Not stated	Sheepshead minnow	0.18 mg/L	NOEC	Eriksson, 1995
	Not stated	Rainbow trout	0.07 mg/L	14 day LC50	Eriksson, 1995
	Not stated	Rainbow trout	0.14 mg/L	24 hour LC50	Eriksson, 1995
	Not stated	Rainbow trout	0.05 mg/L	NOEC	Eriksson, 1995
	Not stated	Fathead minnow	0.23 mg/L	4 day LC100	Eriksson, 1995
	Not stated	Fathead minnow	0.02 mg/L	NOEC	Eriksson, 1995
	14.17%	Rainbow trout	0.19 mg/L	LC50	USEPA, 1998
	14.17%	Rainbow trout	0.07 mg/L	LC50	USEPA, 1998
	14.17%	Bluegill sunfish	0.3 mg/L	LC50	USEPA, 1998
	1.50%	Daphnid Ceriodaphnia	0.2 mg/L	LC50	USEPA, 1998
	14.17%	Daphnid Daphnia	0.18 mg/L	LC50	USEPA, 1998

Table B1: Toxicity Associated with Lower Volume Use Slimicides in Atlantic Canada

Product	A.I.(%)	Test Species	Concentration	Effect/Type of Study	Reference
	13.90%	Sheepshead minnow	0.36 mg/L	LC50	USEPA, 1998
	Not stated	Marine copepod	0.056 mg/L	LC50	USEPA, 1998
	13.90%	Pink shrimp	2.3 mg/L	LC50	USEPA, 1998
	13.90%	Fiddler crab	59 mg/L	LC50	USEPA, 1998
	13.90%	Eastern oyster, embryo, larvae	0.028 mg/L	LC50	USEPA, 1998
Poly[oxyethylene(dimethyliminio)ethylene (dimethyliminio)ethylene dichloride]	60%	Rat	5000 ppm	NOAEL (teratogenic effects)	Eriksson, 1995
	60%	Rabbit	350 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	60%	Rat	15 mg/kg-bw/day	NOAEL (teratogenic effects)	Eriksson, 1995
	60%	Algae	0.12 mg/L	5 day EC50	Eriksson, 1995
	60%	Green algae	9.2 ug/L	5 day EC50	Eriksson, 1995
	60%	Daphnia magna	0.16 mg/L	48 hour LC50	Eriksson, 1995
	60%	Daphnia magna	0.56 mg/L	16 day NOEC	Eriksson, 1995
	60%	Bluegill sunfish	6.7 mg/L	96 hour LC50	Eriksson, 1995
	60%	Sheepshead minnow	>600 mg/L	96 hour LC50	Eriksson, 1995
Disodium ethylenebis (dithiocarbamate)		Rat	8.2 mg/kg-bw/day	NOAEL 90 day rat neurotoxicity study	USEPA, 2001
		Mouse	4.4 mg/kg-bw/day	NOAEL 2 year study - thyroid effects	USEPA, 2001
		Rat	128 mg/kg-bw/day	NOAEL - atrophy of brain tissue	USEPA, 2001
		Rat	4.4 mg/kg-bw/day	NOAEL 2 year study - thyroid effects	USEPA, 2001
Sodium dimethyldithiocarbamate	Not stated	Rat	98.75 mg/kg-bw/day	NOAEL 90 day rat neurotoxicity study	USEPA, 2001
	Not stated	Rat	2 mg/kg-bw/day	NOAEL (decreased maternal body weight)	USEPA, 2001